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(54) **PROCESS AND APPARATUS FOR PARA-XYLENE PRODUCTION USING MULTIPLE ADSORPTIVE SEPARATION UNITS AND MULTIPLE ADSORPTIVE BED FEED POINTS**

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C07C 5/27	(2006.01)
C07C 7/12	(2006.01)
B01D 15/18	(2006.01)
C07C 7/04	(2006.01)
C07C 7/13	(2006.01)
C10G 25/00	(2006.01)

(52) **U.S. Cl.**
CPC *C07C 5/2729* (2013.01); *B01D 15/1828* (2013.01); *C07C 7/04* (2013.01); *C07C 7/12* (2013.01); *C07C 7/13* (2013.01); *C10G 25/00* (2013.01); *C10G 25/12* (2013.01); *C10G 2300/4056* (2013.01); *C10G 2400/30* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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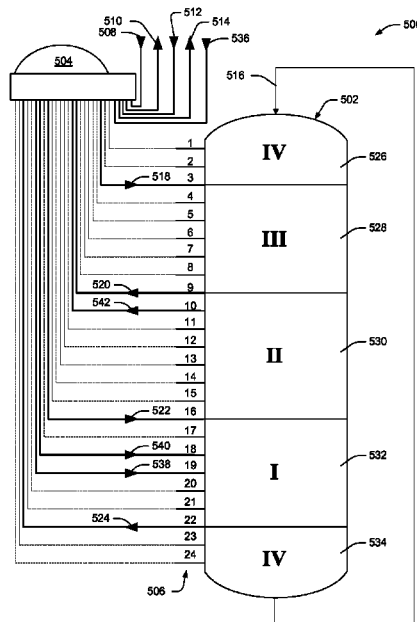|				
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(57) **ABSTRACT**

A process for separating para-xylene from aromatic compounds is presented. The process introduces throughout a first step-time interval a first mixed xylene stream into a first feed input on a first adsorptive separation unit comprising multiple bed lines. The process further introduces throughout the first step-time interval a second mixed xylene stream into a second feed input on the first adsorptive separation unit. During a first portion of the first step-time interval, the process introduces material from a feed stream used during the first step-time interval into a bed line not used to deliver a stream into, or withdraw a stream from, the first adsorptive separation unit during the first step time interval. During a second portion of the first step-time interval, the process introduces material from a purification zone into the feed stream used during the first step-time interval.
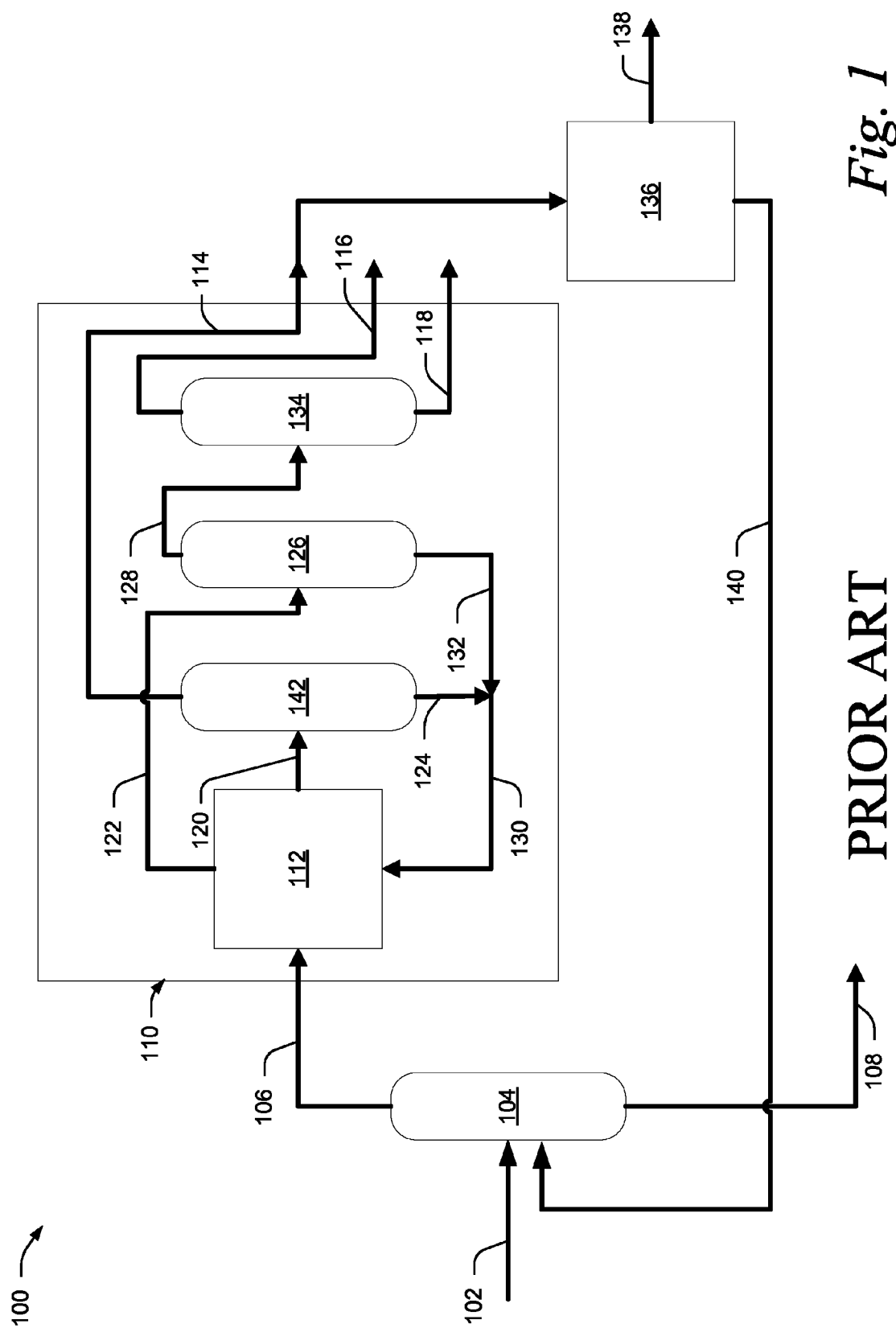
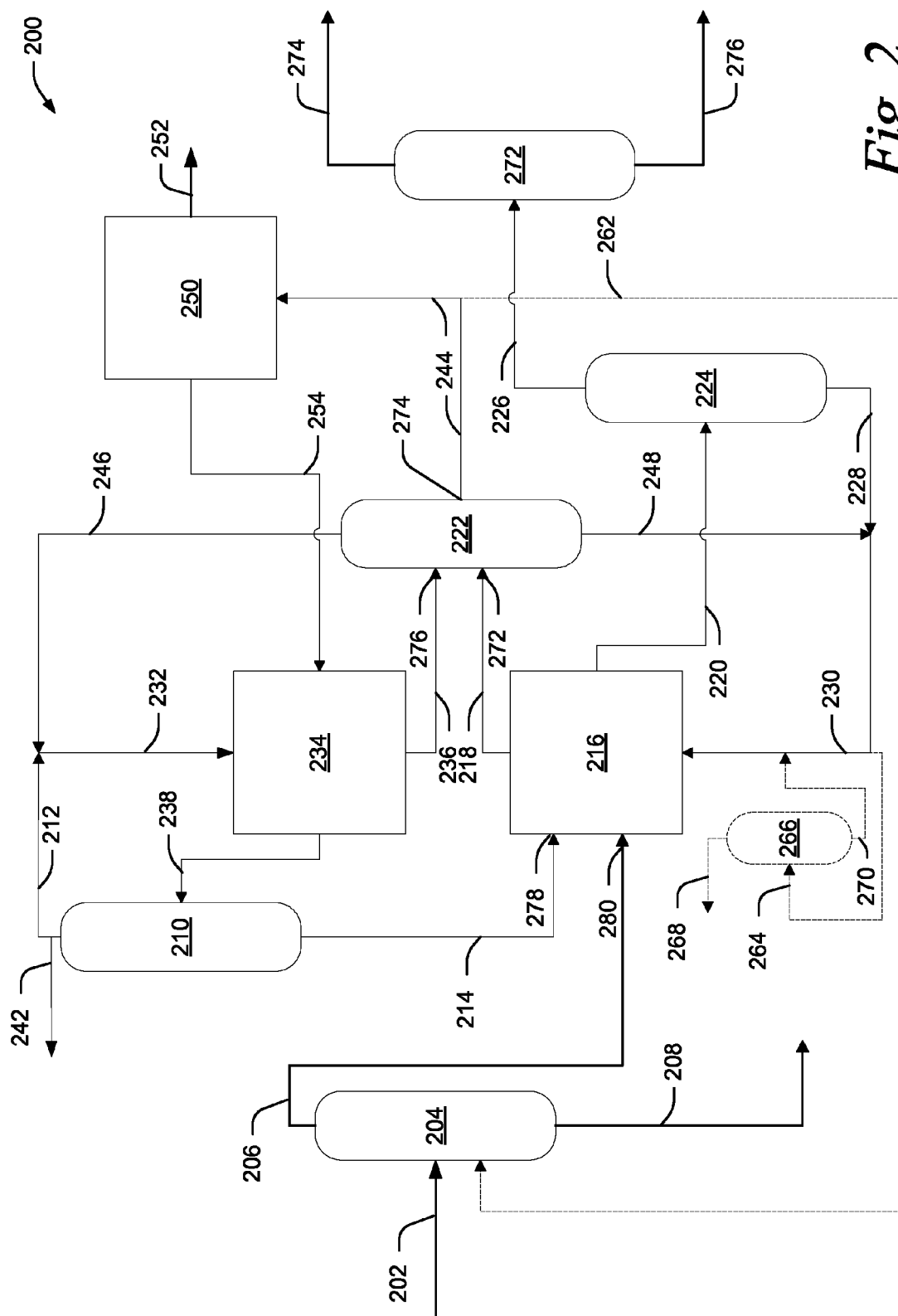**10 Claims, 11 Drawing Sheets**

Fig. 1

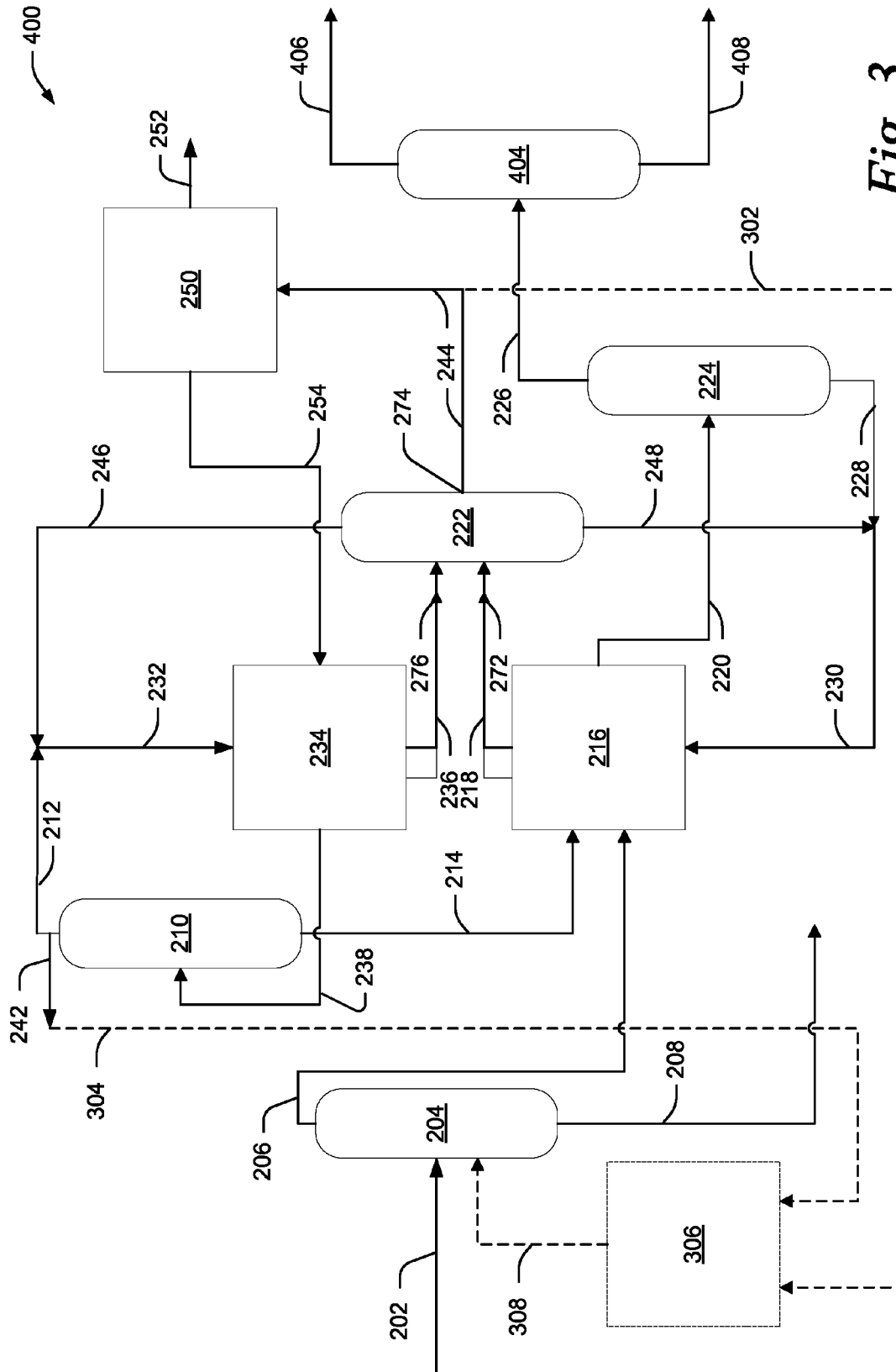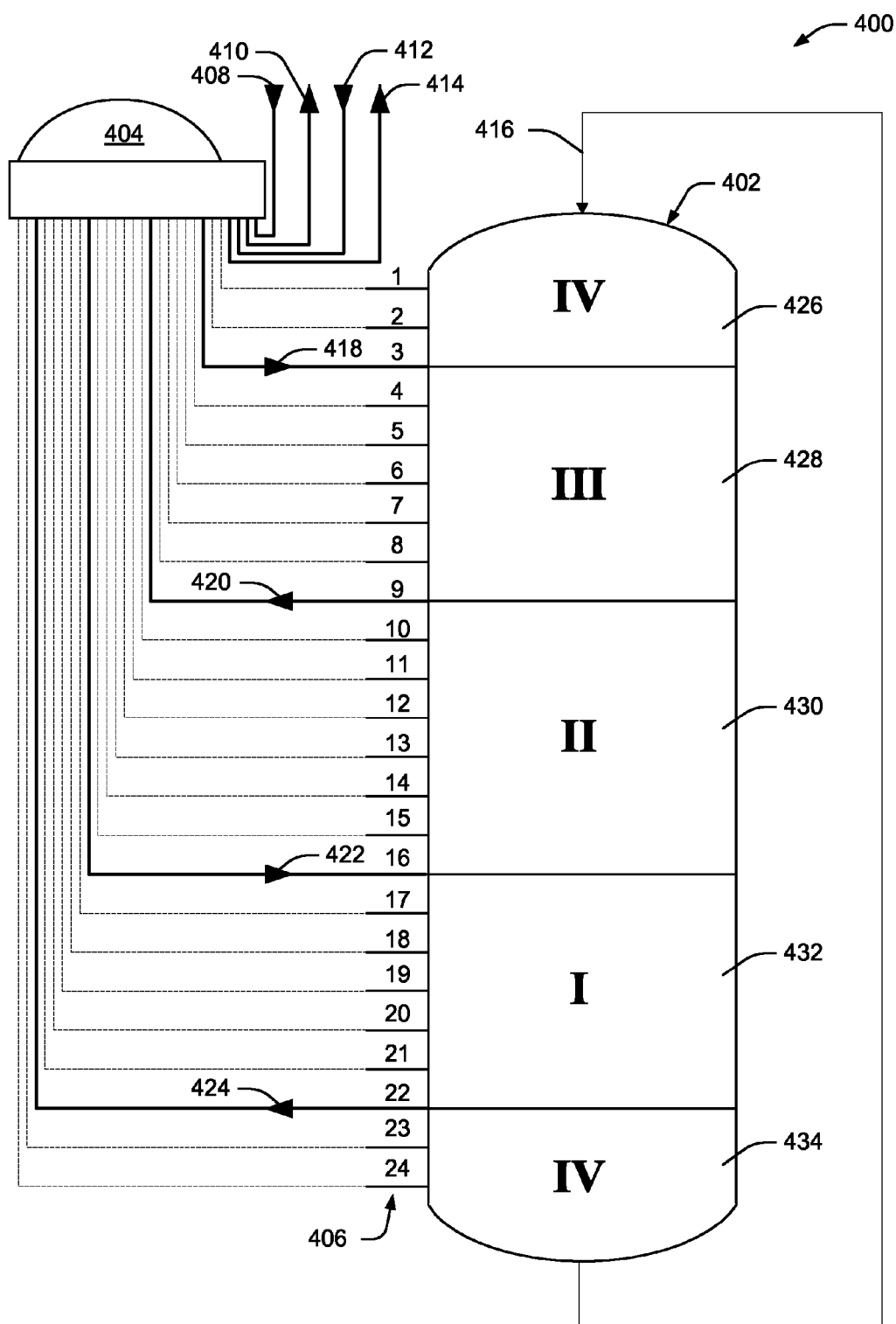PRIOR ART

Fig. 2

Fig. 3

PRIOR ART   *Fig. 4*

Fig. 5

Fig. 6

700
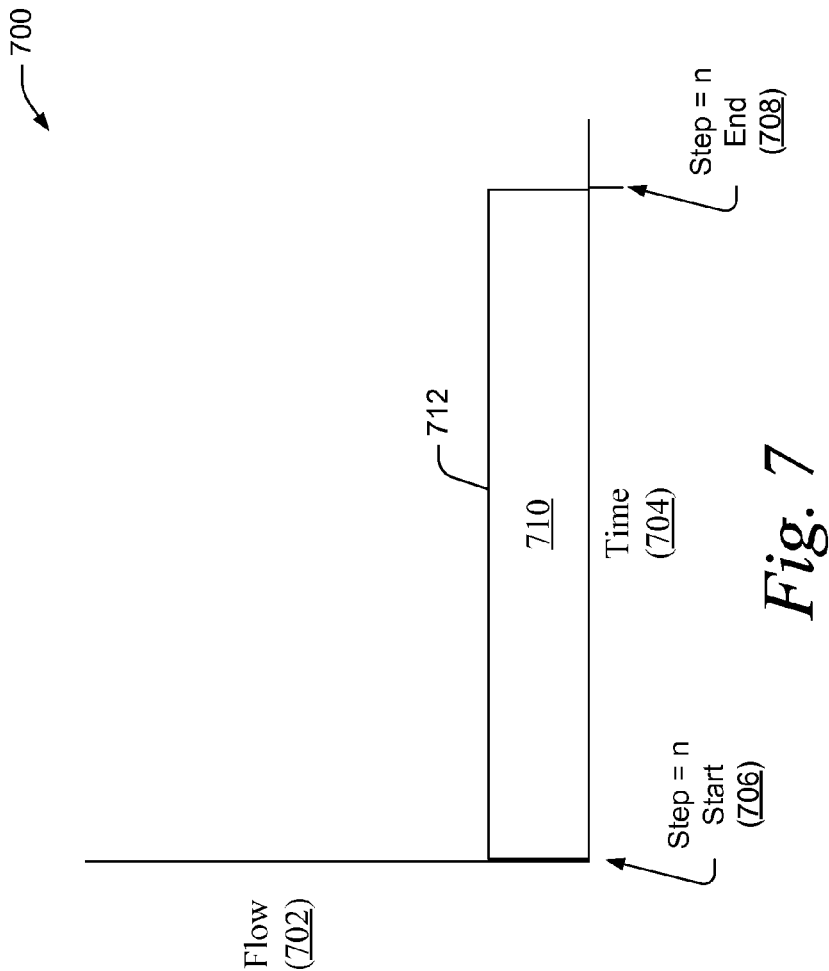
712

710

Step = n
End
(708)

Time
(704)

Step = n
Start
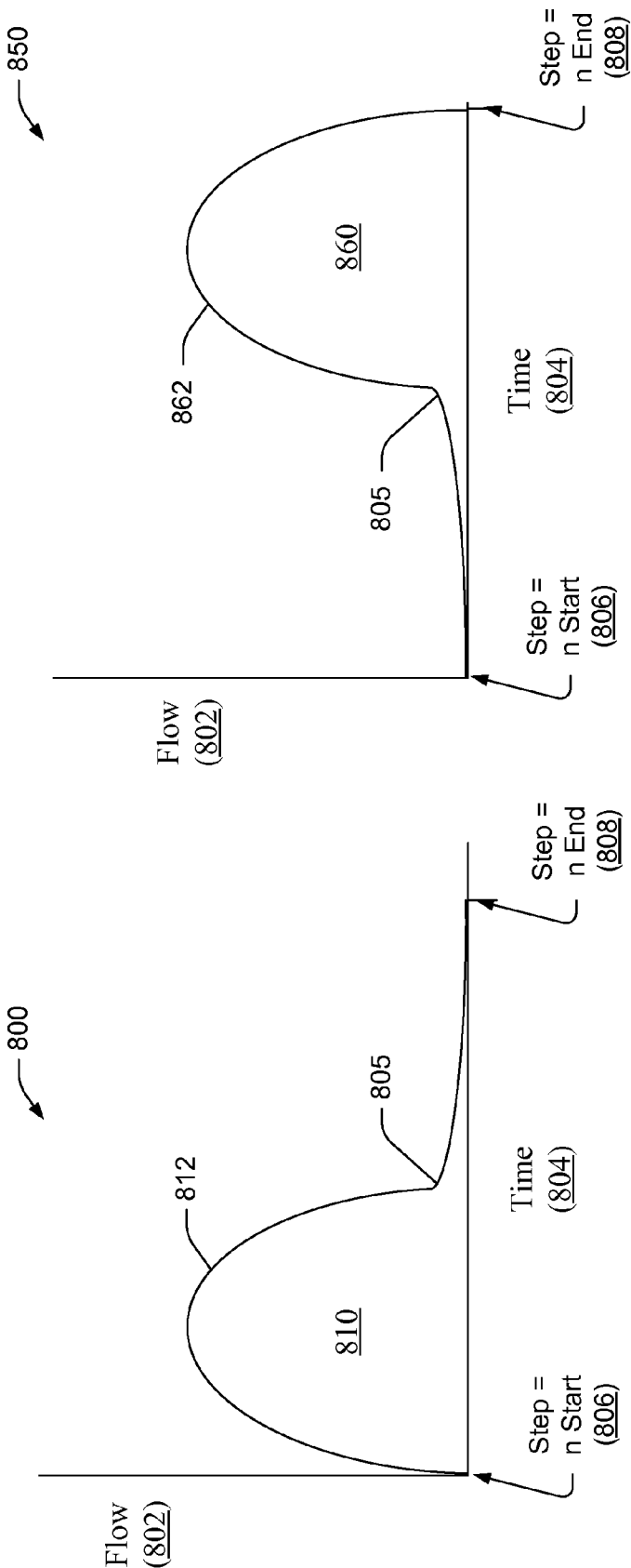(706)

Flow
(702)
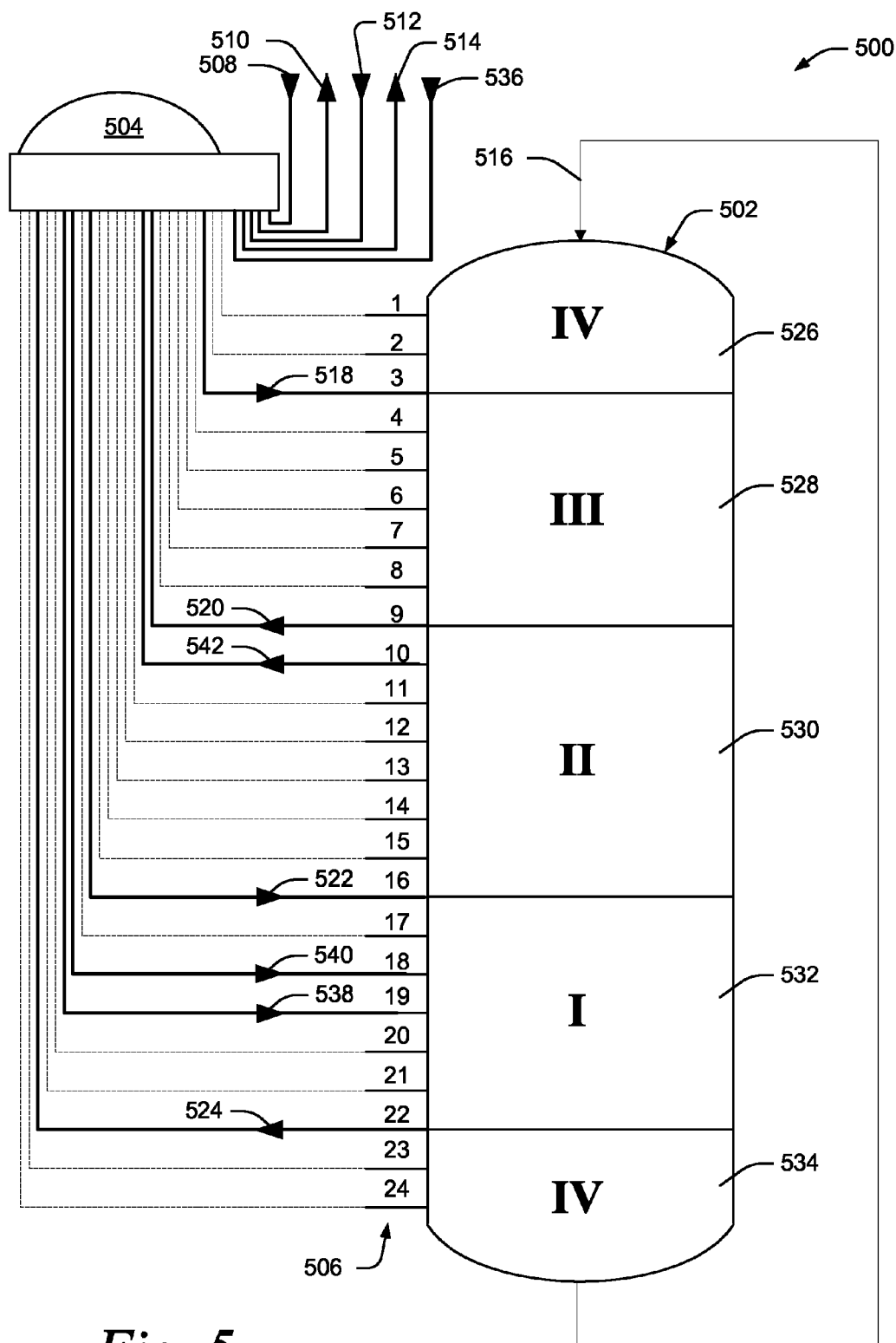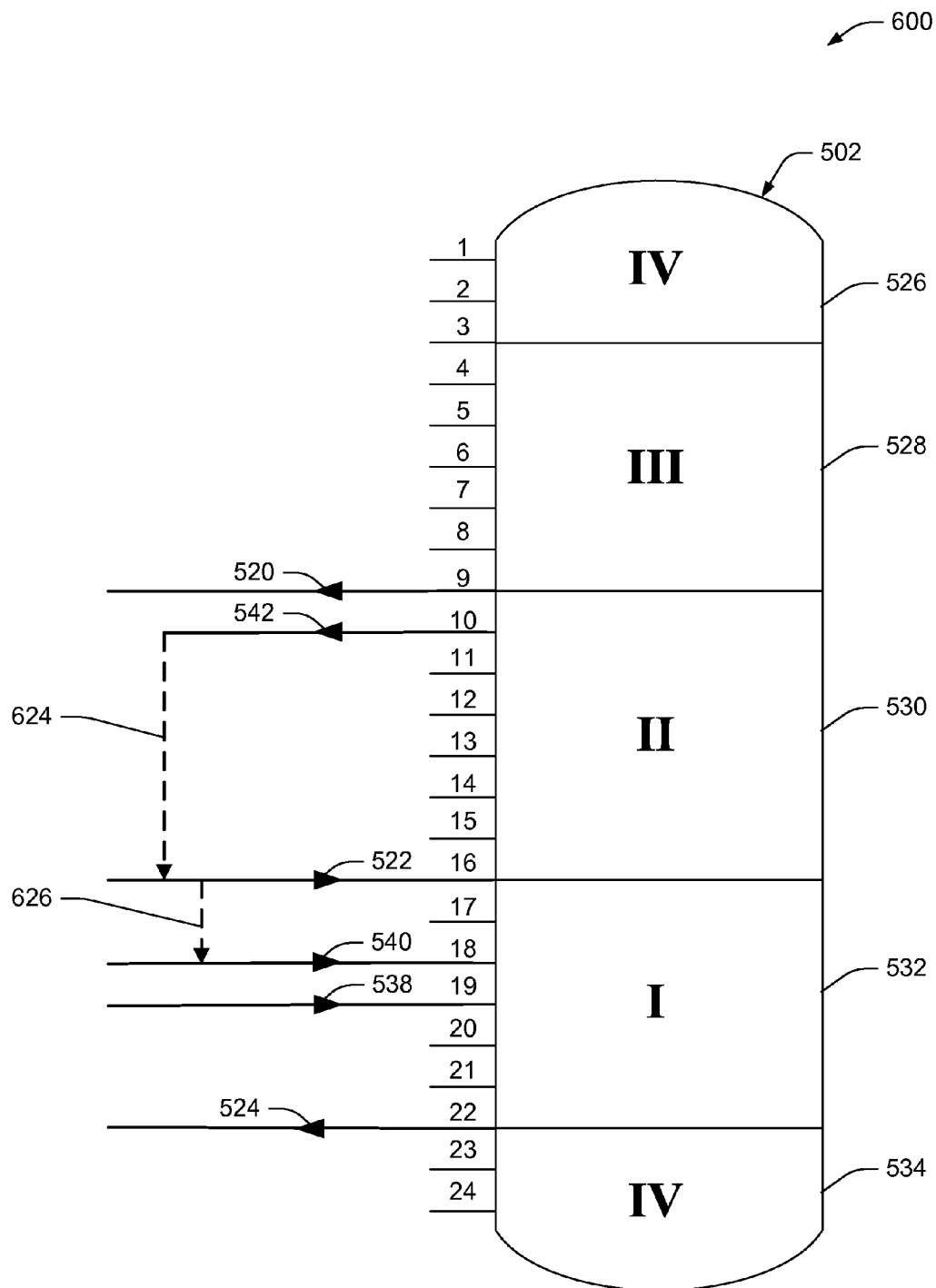
Fig. 7

PRIOR ART

Fig. 8(b)

Fig. 8(a)

Fig. 9

Fig. 10

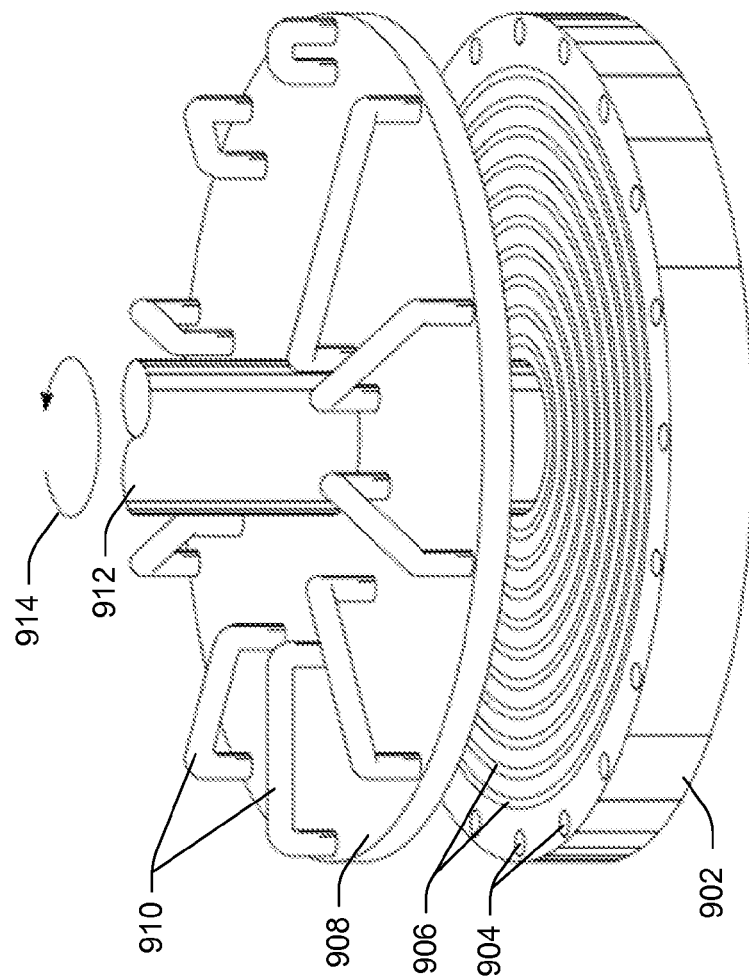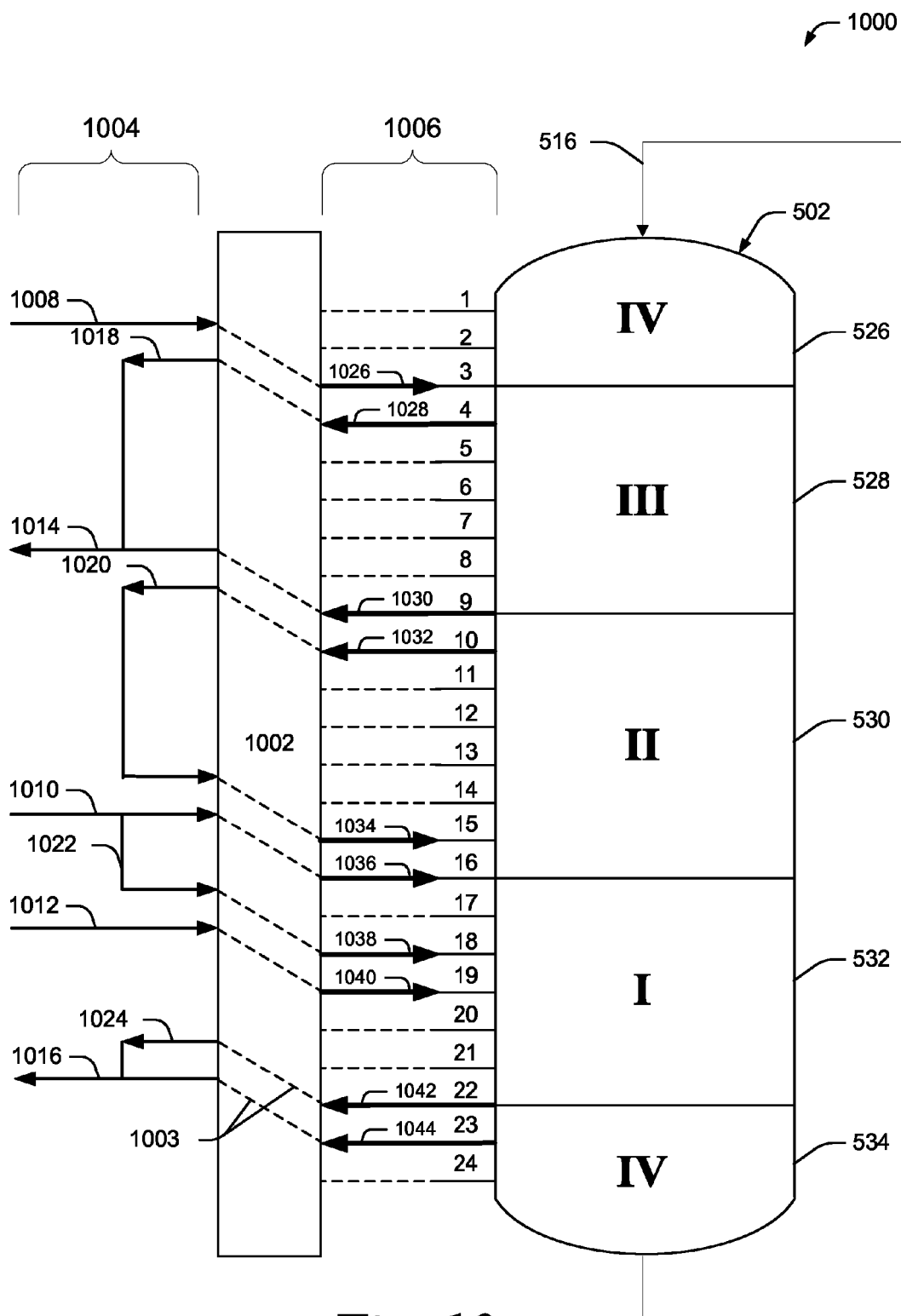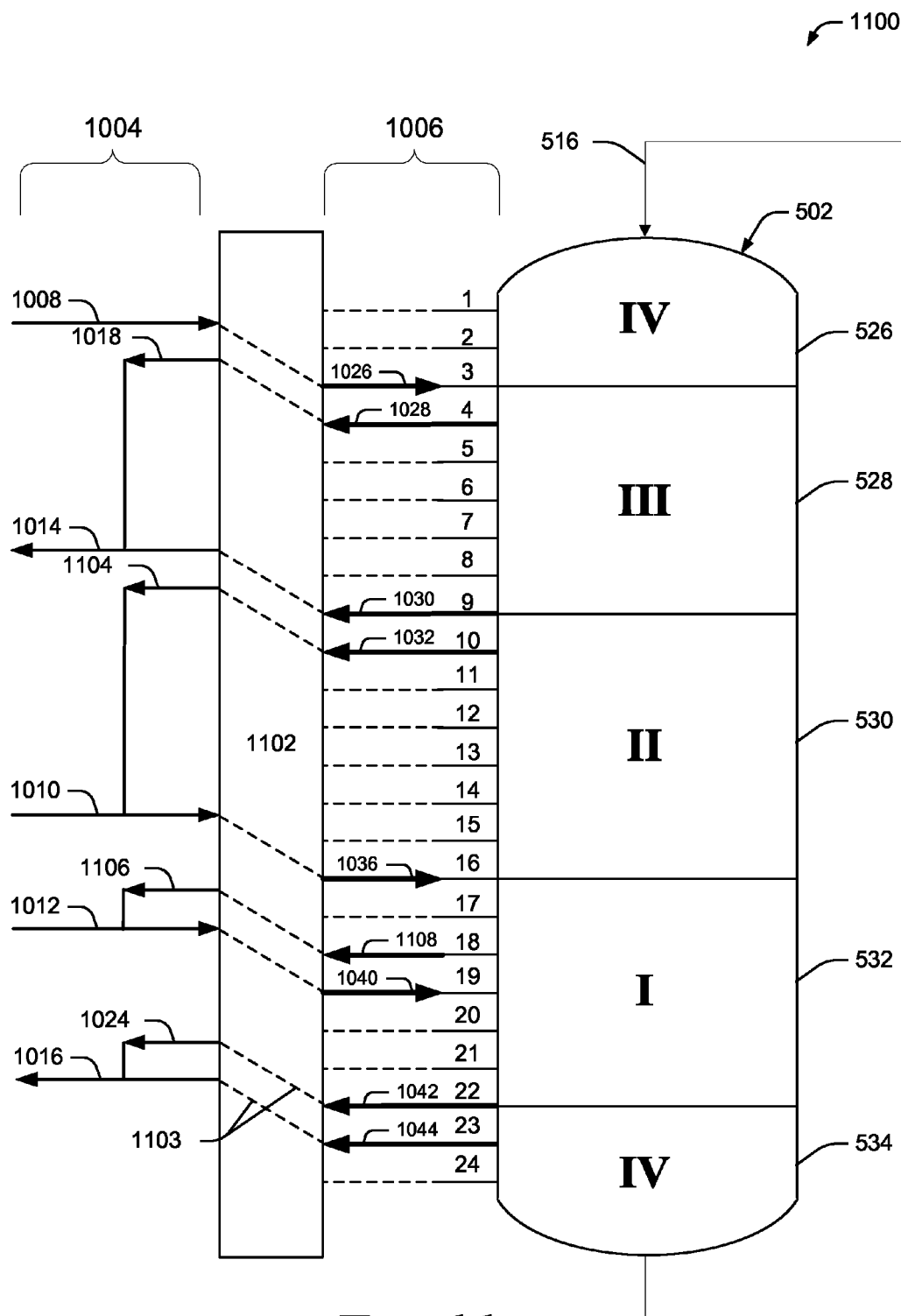*Fig. 11*

PROCESS AND APPARATUS FOR PARA-XYLENE PRODUCTION USING MULTIPLE ADSORPTIVE SEPARATION UNITS AND MULTIPLE ADSORPTIVE BED FEED POINTS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a Division of prior copending U.S. application Ser. No. 13/326,961 which was filed Dec. 15, 2011, the contents of which are incorporated herein by reference thereto.

FIELD OF THE INVENTION

The disclosure relates to a process for the formation and adsorptive separation of a select xylene isomer, preferably para-xylene, from a feed stream containing a mix of aromatic and non-aromatic hydrocarbons. More specifically, the disclosure relates to increasing the efficiency of para-xylene production by eliminating the need to vaporize the product stream from the isomerization process. Most specifically, the disclosure relates to a para-xylene process comprising multiple adsorptive separation units, each using a different desorbent, to eliminate fractional distillation of the isomerized product stream, where one adsorptive separation unit accepts multiple feeds, along with a material transfer configuration to facilitate such multiple feeds.

BACKGROUND OF THE INVENTION

Para-xylene, an aromatic hydrocarbon, is an important intermediate which finds wide and varied application in chemical syntheses. Upon oxidation, para-xylene yields terephthalic acid. Polyester fabrics and resins are produced from a polymer of ethylene glycol and terephthalic acid. These polyester materials are used extensively in a number of industries and are used to manufacture such items as, for example, clothing, beverage containers, electronic components, and insulating materials.

The production of para-xylene is practiced commercially in large-scale facilities and is highly competitive. Concerns exist not only about the effective conversion of feedstock through one or more of isomerization, transalkylation and disproportionation to produce para-xylene, and effective separation of para-xylene from the resultant mixture of C8 aromatic isomers, but also with the energy costs and capital costs associated with such processes.

In prior art processes, C9 aromatics are separated from the C8 aromatics, i.e. xylene isomers, by fractional distillation. This requires heating of the admixture to vaporize the C8 and lighter aromatics. A large portion of the isomerization stream must be vaporized to accomplish the C9 separation because the stream is generally composed primarily of C8 and lighter aromatics. This separation requires a substantial amount of energy and associated cost. After the C9 aromatic removal, the C8-containing stream is then recycled into the adsorptive separation unit.

Accordingly, it would be an advance in the state of the art to provide a process for the production of para-xylene, including separation and isomeric formation from an admixture of C8 aromatic isomers, that removes the need to vaporize the isomerized stream for removal of C9 aromatics, thereby lowering operational expenses, in the form of energy consump-

tion, and capital expenditures, in the form of required processing equipment and the size of such processing equipment.

SUMMARY OF THE INVENTION

A process for separating para-xylene from a plurality of aromatic compounds is presented. The process introduces, throughout a first step-time interval, a first mixed xylene stream comprising a plurality of xylene isomers into a first feed input on a first adsorptive separation unit comprising a plurality of bed lines, wherein that first adsorptive separation unit comprises a purification zone. The process further introduces throughout the first step-time interval a second mixed xylene stream comprising a plurality of xylene isomers into a second feed input on the first adsorptive separation unit.

During a first portion of said first said step-time interval, the process introduces material from a feed stream used during the first step-time interval into a bed line not used during the first step time interval. During a second portion of said first said step-time interval, the process introduces material from the purification zone into the feed stream used during the first step-time interval.

An apparatus for separating para-xylene from a plurality of aromatic compounds is presented. The apparatus comprises a first adsorptive separation unit comprising a rotary valve comprising more than 8 tracks, where the first adsorptive unit is in fluid communication with the rotary valve. The first adsorptive separation unit comprises a first feed input and a second feed input. The apparatus further comprises a second adsorptive separation unit, and a raffinate column in fluid communication with both the first adsorptive separation unit and the second adsorptive separation unit.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of a prior art process;

FIG. **2** is a diagram of one embodiment of the disclosed process having an adsorption unit with multiple feeds where a drag stream is fed into the xylene fractionation column;

FIG. **3** is a diagram of one embodiment of the disclosed process having an adsorption unit with multiple feeds where a drag stream is fed into an aromatic conversion unit;

FIG. **4** is a diagram of a prior art adsorptive separation unit;

FIG. **5** is a diagram of one embodiment of an adsorptive separation unit having multiple feeds and dynamic flushing;

FIG. **6** is a simplified diagram of one embodiment of Applicants' adsorptive separation unit having multiple feeds and dynamic flushing;

FIG. **7** is a chart showing the flush profile of the prior art;

FIGS. **8**(*a*) and **8**(*b*) are charts showing the dynamic flush profile used with Applicant's adsorptive separation unit having multiple feeds;

FIG. **9** is a diagram of one embodiment of a rotary valve for use in Applicant's apparatus and process;

FIG. **10** is a diagram of one embodiment of Applicant's adsorption separation assembly having a multi-feed column and a ten track rotary valve; and

FIG. **11** is a diagram of one embodiment of Applicant's adsorption separation assembly having a multi-feed column and a nine track rotary valve.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Para-xylene is typically recovered from a mixed aromatic hydrocarbon fraction derived from various sources such as catalytic reforming by liquid-liquid extraction and/or frac-

tional distillation. The para-xylene is commercially separated from a feed stream that typically contains all three xylene isomers, namely ortho-xylene, meta-xylene, and para-xylene. The para-xylene, or other desired isomer, is separated by either fractional crystallization or adsorptive separation or a combination of these two techniques. Adsorptive separation is generally preferred as it has a significantly higher single pass recovery (~97%) relative to crystallization separation (~65%).

A typical adsorptive separation process first involves the separation of C8 aromatic hydrocarbons, including ortho-xylene, meta-xylene, para-xylene, and ethylbenzene, from heavier aromatic hydrocarbons (i.e., C9+) and non-aromatic hydrocarbons through fractional distillation.

Those skilled in the art will appreciate that the designator "CX" refers to a compound comprising X carbon atoms, "CX+" refers to a compound comprising X or greater carbon atoms, and "CX–" refers to a compound comprising X or fewer carbon atoms.

The para-xylene isomers are then separated from the C8 isomer admixture using a simulated countercurrent moving-bed (SMB) adsorptive separation unit. This simulation is performed using established commercial technology wherein an adsorbent, commonly a solid zeolitic material, is held in place in one or more cylindrical adsorbent chambers. The positions at which the streams involved in the process enter and leave the chamber(s) are slowly shifted along the height of the chamber(s). Normally there are at least four streams (feed, desorbent, extract and raffinate) employed in this procedure and the location at which the feed and desorbent streams enter the chamber and the extract and raffinate streams leave the chamber are simultaneously shifted in the same direction at set intervals in a step-wise manner. Each shift in location of these transfer points delivers or removes liquid from a different bed within the chamber.

A typical chamber has a single line for each bed. The flow into or out of a particular line, as the case may be, is controlled by a rotary valve. The shifting of streams along the bed simulates movement of the adsorbent in a direction opposite the flow of liquid, even though the adsorbent is fixed in place within the chamber. SMB chambers are also well suited for high volume production because the input and output streams have nearly constant compositions throughout simulated motion of the adsorbent material in the bed.

A typical SMB unit recycles a heavy desorbent, such as para-diethylbenzene, to separate high purity para-xylene from the other C8 isomers. Para-diethylbenzene is a C10 aromatic that is separated from para-xylene by fractional distillation.

The admixture of non-para-xylene isomers from the adsorptive separation unit is subjected to catalytic isomerization to reestablish an equilibrium amount of para-xylene isomers in the admixture. In addition to para-xylene and other C8 isomers, the isomerized stream typically contains an amount of C9+ aromatics, which will accumulate in the desorbent and, therefore, must be removed.

Processes for isolating a desired isomer of xylene without the vaporization of the full isomerized product stream are presented. The process comprises two adsorptive separation units. The first unit utilizes a heavy desorbent and the second unit utilizes a light desorbent. Those skilled in the art will appreciate that a desorbent used in combination with a simulated moving bed adsorbent system facilitates removal of an adsorbed material from the adsorbent bed. This being the case, a useful desorbent will have an affinity for the desired material, i.e., para-xylene, that is substantially the same as the affinity of the adsorbent bed for that desired material.

As used herein, the terms heavy and light are generally in reference to the boiling point of the desorbent relative to the C8 aromatics, namely, ortho-, meta-, para-xylene and ethylbenzene.

In certain embodiments, the heavy desorbent is selected from the group consisting of para-diethylbenzene, para-di-isopropylbenzene, tetralin, and the like, and combinations thereof. In certain embodiments, toluene and the like can be used as the light desorbent. The para-diethylbenzene has a higher boiling point than the C8 aromatic isomers and, as such, the para-diethylbenzene is the bottoms (i.e., heavy) product when separated from the C8 isomers in a fractional distillation column. Similarly, toluene has a lower boiling point than the C8 aromatic isomers and, as such, the toluene is the overhead (i.e., light) product when separated from the C8 isomers in a fractional distillation column.

Unlike prior art processes, Applicant's process comprises feeding a stream of material containing a desired xylene isomer formed in an isomerization unit into a second adsorptive separation unit, as opposed to being fed back into a fractional distillation column. An extract stream from the second adsorptive separation unit, rich in the desired xylene isomer, is fed back into a first adsorptive separation unit for isolation of the desired xylene isomer. The process is presented in greater detail below.

Referring to FIG. 1, a diagram 100 of a prior art process for the production of para-xylene is depicted. A feed stream 102 enters a xylene fractionation unit 104. The feed stream typically contains ortho-, meta-, and para-xylene isomers and may also contain quantities of ethylbenzene, toluene, C8 cycloalkanes, alkanes, and hydrocarbons having more than eight carbon atoms per molecule.

The xylene fractionation unit 104 is a fractional distillation column. The xylene fractionation unit 104 divides the incoming stream into an overhead stream 106 comprising the C8 and lighter aromatics, including the xylene isomers, ethylbenzene, and toluene, and a bottoms 108 and one or more side cut streams (not shown) comprising C9+ aromatics.

Table 1 recites an example composition for feed stream 102.

TABLE 1

Component	Amount
para-xylene	10-20 wt %
Total C8 Aromatics	25-60 wt %
ethylbenzene	10-20 wt %
toluene	0.5-2.0 wt %
C9+	25-30 wt %
Nonaromatic hydrocarbons	<0.5 wt %
Nitrogen	1.0 mg/kg
Sulfur	1.0 mg/kg

The overhead stream 106 enters the separation assembly 110, where the input stream 106 is separated into a raffinate stream 114, a toluene stream 116, and a para-xylene stream 118. The raffinate stream 114 has been substantially depleted of para-xylene but contains other C8 aromatics, including ortho-xylene, meta-xylene and ethylbenzene.

Within the separation assembly 110, the stream 106 enters an adsorptive separation unit 112. The adsorptive separation unit 112 separates the incoming stream 106 into a raffinate stream 120 and an extract stream 122. The adsorptive unit 112 typically comprises two SMB chambers and a rotary valve. Each individual chamber typically has 12 beds. A bed line connects each bed to the rotary valve. The rotary valve con-

trols the flow of material into or out of each SMB chamber in a step-wise manner to create a simulated moving bed.

A heavy desorbent, typically para-diethylbenzene, is used to facilitate the separation of the raffinate stream **120** and extract stream **122**. The raffinate stream **120** comprises ethylbenzene, meta-xylene, and ortho-xylene diluted with desorbent and any heavies. Heavies are hydrocarbons with a boiling point greater than that of the C8 aromatic isomers and include C9+ aromatics. The extract stream **122** comprises para-xylene diluted with desorbent and light ends. Light ends are hydrocarbons with a boiling point below that of the C8 aromatic isomers and include toluene and other C7– aromatics.

The raffinate stream **120** is directed to a raffinate column **142**. The raffinate column **142** is a fractional distillation column that divides the incoming stream **120** into (i) an overhead raffinate stream **114** comprising ethylbenzene, meta-xylene, and ortho-xylene and (ii) a bottoms stream **124** comprising desorbent and any heavies. The bottoms stream **124** is recycled back to the adsorptive unit **112** through combined stream **130**. The overhead raffinate stream **114** is directed to an isomerization unit **136**.

The extract stream **122**, comprising xylene isomers and ethylbenzene, enters extract column **126**. Extract column **126** is a fractional distillation column that divides the incoming stream **122** into (i) an overhead stream **128** comprising para-xylene and toluene and (ii) a bottoms stream **132** comprising desorbent and heavies. The bottoms stream **132** containing desorbent is recycled back to the adsorptive unit **112** through combined stream **130**. Heavies in the combined desorbent stream **130** may be removed by directing a slipstream of the desorbent into a small desorbent rerun column.

The overhead stream **128**, comprising para-xylene and toluene, enters finishing column **134**. Finishing column **134** is a fractional distillation column that divides the incoming stream **128** into (i) an overhead toluene stream **116** and (ii) a bottoms para-xylene stream **118**. The bottoms para-xylene stream **118** contains the final desired product.

The raffinate stream **114** comprising ethylbenzene, meta-xylene, and ortho-xylene enters an isomerization unit **136**. Catalysts in the isomerization unit **136** reestablish an equilibrium mixture of the ortho-, meta-, and para-xylene isomers and convert the ethylbenzene into xylenes and/or benzene.

Nonaromatic compounds in the raffinate stream **114** are cracked to light ends and removed in stream **138** along with any benzene. The isomerization process also creates quantities of C9+ aromatics. The output stream **140** comprises an equilibrium mixture of xylene isomers as well as quantities of C9 aromatics and unreacted ethylbenzene. The output stream **140** is recycled back into the xylene fractionation unit **104**.

The C9 aromatics produced during isomerization are separated from the C8 isomers in the xylene fractionation unit **104**. While the C9 aromatics are only a very small portion of the stream, the entire C8 fraction must be vaporized to accomplish this separation.

FIG. **2** illustrates embodiment **200** of Applicant's apparatus and process. A feed stream **202** enters a xylene fractionation unit **204**. In one embodiment, the feed stream **202** contains ortho-, meta-, and para-xylene isomers. In one embodiment, the feed stream **202** contains quantities of ethylbenzene, toluene, C8 cycloalkanes, alkanes, and hydrocarbons having more than eight carbon atoms per molecule.

In one embodiment, the feed stream **202** is a result of hydrotreating naphtha to remove any sulfur and nitrogen contaminants and the subsequent catalytic reforming where paraffins and naphthenes in the decontaminated naphtha are converted to aromatics. The most light ends and C7– fractions are

removed in a debutanizer and fractional distillation column, respectively. The feed stream **202**, comprising a C8+ fraction, enters the xylene fractionation unit **204**. In one embodiment, the feed stream **202** comprises about 23 weight percent para-xylene.

The xylene fractionation unit **204** is a fractional distillation column. The xylene fractionation unit **204** divides the incoming stream into an overhead stream **206** comprising the C8– aromatics, including the xylene isomers, ethylbenzene, and toluene, and a bottoms stream **208** and one or more side cut streams (not shown) comprising C9+ aromatics present in the feed stream **202**.

The overhead stream **206** and bottoms stream **214** from extract column **210** enter adsorptive separation unit **216** at a first feed input **278** and a second feed input **280**, respectively. Adsorptive separation unit **216** separates the incoming streams **206** and **214** into a raffinate stream **218** and an extract stream **220**. In one embodiment, the heavy desorbent para-diethylbenzene is used to facilitate the separation of the raffinate stream **218** and extract stream **220**. In certain embodiments, the heavy desorbent is selected from the group consisting of para-diethylbenzene, para-diisopropylbenzene, tetralin, and the like, and combinations thereof. The raffinate stream **218** comprises ethylbenzene, meta-xylene, and ortho-xylene diluted with desorbent. The extract stream **220** comprises para-xylene diluted with desorbent.

In one embodiment, adsorptive unit **216** comprises an SMB assembly and a rotary valve. In other embodiments, the adsorption separation unit **216** comprises an SMB assembly and one or more rotary valves, one or more computing device operated valves, or a combination thereof. In one embodiment, the SMB assembly comprises a single physical chamber. In one embodiment, the physical chamber includes 24 beds. In one embodiment, the physical chamber includes less than 24 beds. In one embodiment, the SMB assembly includes two physical chambers. In one embodiment, each physical chamber includes 12 beds. In one embodiment, each physical chamber includes less than 12 beds. In one embodiment, each physical chamber includes more than 12 beds. In one embodiment, the physical chambers have an unequal number of beds. A bed line connects each bed in the SMB assembly to the rotary valve. The rotary valve controls the flow of material into or out of the SMB assembly in a step-wise manner to create a simulated moving bed and to flush the bed lines between flows of differing materials.

In certain embodiments, the selectivity of the adsorbent in the adsorptive separation unit **216** for C7– aromatics and light ends is very close to that of para-xylene. As such, the C7– aromatics and light ends exit the adsorptive separation unit **216** by way of extract stream **220**.

The extract stream **220** enters the extract column **224**. Extract column **224** is a fractional distillation column that separates the incoming stream **220** into (i) an overhead para-xylene stream **226** comprising para-xylene, C7– aromatics, and light ends and (ii) a bottoms stream **228** comprising a heavy desorbent fraction, such as para-diethylbenzene, a C10 aromatic. The bottoms stream **228** is recycled back to the adsorptive separation unit **216** through combined stream **230**.

Light desorbent enters adsorptive separation unit **234** by way of combined stream **232**. Adsorptive separation unit **234** separates an incoming stream **254** into a raffinate stream **236** and an extract stream **238**. Stream **254** is an isomerized stream from isomerization unit **250** comprising an equilibrium mixture of xylene isomers.

In one embodiment, the light desorbent toluene is used to facilitate the separation of the raffinate stream **236** and extract stream **238**. In another embodiment, a light desorbent other

than toluene is used to facilitate the separation of the raffinate stream **236** and extract stream **238**. The raffinate stream **236** comprises ethylbenzene, meta-xylene, and ortho-xylene diluted with desorbent. The extract stream **238** comprises para-xylene diluted with desorbent.

In one embodiment, adsorptive unit **234** comprises an SMB assembly and a rotary valve. In other embodiments, the adsorption separation unit **234** comprises an SMB assembly and one or more rotary valves, one or more computing device operated valves, or a combination thereof. In one embodiment, the SMB assembly comprises a single physical chamber. In one embodiment, the physical chamber includes 24 beds. In one embodiment, the physical chamber includes less than 24 beds. In one embodiment, the SMB assembly includes two physical chambers. In one embodiment, each physical chamber includes 12 beds. In one embodiment, each physical chamber includes less than 12 beds. In one embodiment, each physical chamber includes more than 12 beds. In one embodiment, the physical chambers have an unequal number of beds. A bed line connects each bed in the SMB assembly to the rotary valve. The rotary valve controls the flow of material into or out of the SMB assembly in a stepwise manner to create a simulated moving bed and to flush the bed lines between flows of differing materials.

The raffinate stream **236** enters a raffinate column **222** at a third location **276**.

The extract stream **238** is fed into extract column **210**, a fractional distillation column. Extract column **210** separates the para-xylene product in the extract stream **238** from the light desorbent, such as toluene. The overhead stream **212** comprises C7-aromatics and light impurities. The bottoms stream **214** comprises C8 aromatic isomers, including para-xylene. The light desorbent is recycled in a light desorbent loop **212**, **232**, **238**.

In one embodiment, a slipstream **242** is extracted from the overhead stream **212**. In one embodiment, slipstream **242** prevents the accumulation of additional toluene introduced into the desorbent loop from the feed stream **202**. In one embodiment, slipstream **242** prevents the accumulation of light impurities in the light desorbent loop. In one embodiment, slipstream **242** comprises high purity toluene. In one embodiment, slipstream **242** comprises toluene and light impurities from the feed stream **202**.

Raffinate column **222** is a fractional distillation column that separates the raffinate stream **236** and **218**, each comprising para-xylene depleted C8 aromatic isomers diluted with light and heavy desorbent, respectively, into a C8 aromatic isomer stream **244**, a light desorbent stream **246**, and a heavy desorbent stream **248**. The C8 aromatic isomer stream **244** exits the raffinate column **222** at a second location **274**.

The light desorbent along with any light impurities have the lowest boiling point and are, as such, extracted as a net overhead stream **246**. The heavy desorbent along with any heavies have the highest boiling point and are, as such, extracted as a net bottoms stream **248**. The ortho-xylene, meta-xylene, and ethylbenzene have an intermediate boiling point and are, as such, extracted at a sidecut tray. The heavy desorbent is recycled in a heavy desorbent loop **230**, **220/218**, **228/248**.

In one embodiment, the C8 aromatic isomer stream **244** exits the raffinate column **222** at a location below that of raffinate stream **236** and above that of raffinate stream **218**. In one embodiment, the raffinate stream **236** enters raffinate column **222** at a location on the column where the composition within the column **222** is similar to the composition in stream **236**. In one embodiment, the raffinate stream **218** enters raffinate column **222** at a location on the column where

the composition within the column **222** is similar to the composition in stream **218**. As used herein, with reference to fractional distillation columns, the term "above" refers to a location in or on the column such that liquid inserted at the location will flow down toward the reference point. Similarly, the term "below" refers to a location in or on the column such that liquid inserted at the location will flow down away from the reference point.

The C8 aromatic isomer stream **244** comprising meta-xylene, ortho-xylene, and ethylbenzene enters an isomerization unit **250**. Catalysts in the isomerization unit **250** reestablish an equilibrium mixture of the ortho-, meta-, and para-xylene isomers. In one embodiment, the catalyst is an ethylbenzene dealkylation catalyst, which converts ethylbenzene to a benzene co-product. In one embodiment, the catalyst is an ethylbenzene isomerization catalyst, which converts the ethylbenzene into additional xylene isomers.

Nonaromatic compounds in the C8 aromatic isomers stream **244** are cracked to light ends and removed in stream **252** along with any benzene co-product created. The isomerization process may also create small quantities of C9 and heavier aromatics. In one embodiment, the output stream **254** comprises an equilibrium mixture of xylene isomers. In one embodiment, the output stream **254** comprises small quantities of C9+ aromatics. In one embodiment, the output stream **254** comprises unreacted ethylbenzene. In one embodiment, the output stream **254** comprises about 1.5 weight percent ethylbenzene or less. The isomerized output stream **254** enters adsorptive separation unit **234**.

In certain embodiments, certain C9+ aromatics may be introduced by isomerization unit **250** and accumulate in the heavy desorbent loop **230**, **220/218**, **228/248**. In certain configurations of the raffinate column **222**, any C9 aromatics will accumulate in the isomerization loop **254**, **236**, **244**. In other configurations of the raffinate column **222**, any C9 aromatics will accumulate in the heavy desorbent loop **230**, **220/218**, **228/248**. In yet other configurations of the raffinate column **222**, any C9 aromatics will accumulate in both the isomerization loop and the heavy desorbent loop.

In different embodiments, one or more drag streams are used to prevent the accumulation of C9+ aromatics in the process. In one embodiment, if accumulation occurs in the heavy desorbent loop, a drag stream **264** is withdrawn from the desorbent loop by way of stream **230**. Stream **230** comprises primarily heavy desorbent along with the C9 aromatic and heavy impurities. The drag stream **264** is fed into a fractional distillation column **266**, which separates the drag stream **264** into an overhead stream **268** and a bottoms stream **270**. The bottoms stream **270** comprises high purity para-diethylbenzene, which is returned to the desorbent loop by way of stream **230**. In one embodiment, the amount of material withdrawn in drag stream **264** is about 1 to about 20 volume percent of stream **230**.

In another embodiment, if accumulation occurs in the isomerization loop (i.e., **254**, **236**, **244**), a drag stream **262** is withdrawn from the isomerization loop by way of raffinate stream **244**. Stream **244** comprises a mixture of ortho-xylene, meta-xylene, ethylbenzene along with the C9 aromatic and heavy impurities. The drag stream is fed into the xylene fractionation column **204** where substantially all C9+ aromatics are removed in bottoms **208** and the C8 aromatics are recycled back through the process. In one embodiment, the amount of material in the drag stream **262** is about 1 to about 20 volume percent of the raffinate stream **244**.

In yet another embodiment, if the accumulation occurs in both the isomerization loop and the heavy desorbent loop, drag streams **262** and **264** are both used. In other embodi-

ments, no drag streams are used. In other embodiments, the impurities are extracted by another process known in the art capable of separating C9 aromatics and heavies from para-diethylbenzene.

The finishing column 272 separates the overhead stream 226 into an overhead stream 274 comprising C7− aromatics and light ends that entered the process by way of feed stream 202 and a bottoms stream 276 comprising high purity para-xylene.

In certain embodiments, para-ethyltoluene, structurally similar to para-xylene, may be introduced into the process by the isomerization unit 250. In some embodiments, the para-ethyltoluene may not be fully separated from the para-xylene in the adsorptive separation unit 216, in the extract column 224, or in the finishing column 272 and exists as in impurity in the para-xylene product stream 276. In some embodiments, the para-ethyltoluene is removed from the para-xylene product using any technique known in the art capable of separating para-ethyltoluene from a stream of para-xylene.

In one embodiment, the bottoms para-xylene stream 276 comprises about 99.2 weight percent para-xylene. In one embodiment, the bottoms para-xylene stream 276 comprises about 99.7 weight percent para-xylene. In one embodiment, the bottoms para-xylene stream 276 comprises about 99.9 weight percent para-xylene. In one embodiment, the bottoms para-xylene stream 276 comprises greater than about 99.9 weight percent para-xylene.

Referring to FIG. 3, diagram 300 illustrates one embodiment of Applicant's apparatus and process including an aromatic conversion unit. To prevent accumulation of C9 aromatics in the isomerization loop (i.e., 254, 236, 244), a drag stream 302 is withdrawn from the isomerization loop by way of raffinate stream 244. The drag stream is fed into an aromatic conversion unit 306. All or a portion of the light desorbent slip stream 242, comprising toluene, is directed into the aromatic conversion unit 306 by way of stream 304.

The aromatic conversion unit 306 converts the incoming stream 304 comprising a mixture of toluene and C7− aromatics into an output stream 308 comprising an equilibrium mixture of xylene isomers and ethylbenzene. The aromatic conversion unit 306 facilitates catalytic disproportionation reactions, which convert toluene into a mixture of benzene and xylene isomers. In one embodiment, any C7− aromatics produced are removed from aromatic unit 306 (stream not shown). The aromatic unit 306 also facilitates catalytic transalkylation reactions, which convert a blend of toluene and C9 aromatic isomers to xylene isomers through the migration of methyl groups between methyl-substituted aromatics.

The aromatic conversion product stream 308 enters the xylene fractionation unit 204. The C8− aromatics exit the xylene fractionation unit 204 by way of stream 206. The C9+ aromatics exit the xylene fractionation unit by way of stream 208.

FIG. 4 illustrates a prior art adsorptive separation unit 400. The unit 400 includes a housing 402. The adsorptive separation unit 400 contains a solid zeolitic adsorbent and a number of beds with corresponding bed lines 406.

As material is fed into the chamber and flows downwardly, the material contacts the solid adsorbent within the chamber. The adsorbent having an affinity for the desired xylene isomer is selected for the chamber. Certain types of zeolitic adsorbents have an affinity for para-xylene. As the feed stream flows over the solid adsorbent, the para-xylene is selectively adsorbed into the adsorbent while the other isomers continue to travel downward in the chamber in the bulk liquid. Material that reaches the bottom of the chamber is reinserted into the

top of the chamber by way of recycle line 416 to create a continuous flow of bulk liquid.

While a single chamber 402 is shown, the chamber 402 may be split into two or more individual chambers, with the bottom of a given chamber in fluid communication with the top of another chamber to create a functional equivalent of chamber 402.

A rotary valve 404 controls the flow of material into and out of the bed lines 406 and the net flow of material into and out of the assembly 400 through the assembly inputs and outputs, including feed input 408, raffinate output 410, desorbent input 412, and extract output 414. A feed stream comprising mixed xylene isomers is fed into line 408. A desorbent stream comprising para-diethylbenzene, is fed into the desorbent input 412. An extract stream of high purity para-xylene is withdrawn from extract output 414. A raffinate stream of para-xylene-depleted C8 aromatics is withdrawn from raffinate output 410.

The rotary valve 404 directs the stream of material from each of the assembly inputs and outputs to specific bed lines. The rotary valve has 24 steps, each corresponding to a particular configuration of input and output streams to the bed lines 406. As the rotary valve moves from one step to the next, the streams from the assembly inputs and outputs each move to the next bed line lower on the chamber. For example, at step 1, the raffinate stream may initially be pulled from bed line 22. In subsequent steps 2, 3, and 4, the raffinate stream will be pulled from bed line 23, 24, and 1, respectively. The rotary valve also controls a number of flush lines (not shown) to flush the bed lines of material (i.e., extract, feed, raffinate, or desorbent) from a previous step, using a constant flush line flow, to prepare the bed lines for a future step (i.e., desorbent, extract, feed, and raffinate, respectively).

The routing of the assembly input and output streams by the rotary valve 404 to the chamber 402 for step=n is shown in FIG. 4. In the interest of clarity, the streams were equally distributed along the heights of chamber 402 in FIG. 4. The feed stream 422 is routed to bed line 16, the raffinate stream 424 is routed from bed line 22, the desorbent stream 418 is routed to bed line 3, and the extract stream 420 is routed from bed line 9.

The adsorption zone 432 (Zone I) is defined as the portion of the chamber between the feed stream 422 and the raffinate stream 424, where the para-xylene is adsorbed into the solid adsorbent.

The desorption zone 428 (Zone III) is defined as the portion of the chamber between the desorbent stream 418 and the extract stream 420. The desorbent is selected to have approximately the same affinity for solid adsorbent as the desired xylene isomer. As such, the desorbent washes (i.e., desorbs) the adsorbed para-xylene from the solid adsorbent.

The purification zone 430 (Zone II) is defined as the portion of the chamber between the extract stream 420 and the feed stream 422. In the purification zone 430, the higher affinity para-xylene displaces other xylene isomers within the adsorbent back into the bulk solution, thereby flushing the other xylene isomers down the chamber.

The buffer zone 426 and 434 (Zone IV) is defined as the portion of the chamber between the raffinate stream 424 and the desorbent stream 418. The buffer zone 426/434 allows the undesired xylene isomers (i.e., ortho- and meta-xylene) to be extracted by the raffinate stream before the extraction of the desired xylene isomer (i.e., para-xylene) is initiated by the desorbent stream 418.

As the rotary valve advances to step n+1, the position of the desorbent stream 418 transitions from bed line 3 to bed line 4, the position of the extract stream 420 transitions from bed line

9 to bed line 10, the position of the feed stream 422 transitions from bed line 16 to bed line 17, and the position of the raffinate stream 424 transitions from bed line 22 to bed line 23. The streams transition in similar fashion for each subsequent set n+2 to n+23, after which the rotary valve returns to step=n as shown in FIG. 4.

Referring to FIG. 5, a diagram illustrates one embodiment of Applicant's adsorptive separation assembly 500. The assembly 500 comprises an adsorption chamber 502. In one embodiment, the adsorption chamber 502 contains a solid zeolitic adsorbent and a number of beds with corresponding bed lines 506. The number of beds may vary.

As material is fed into the chamber and flows downwardly, the material contacts the solid adsorbent within the chamber. The adsorbent with the an affinity for the desired xylene isomer is selected for the chamber. Para-xylene isomer has a particular affinity for certain types of zeolitic adsorbents. As the feed stream flows over the solid adsorbents, the para-xylene is selectively adsorbed into the adsorbent while the other isomers continue to travel downward in the chamber. Material that reaches the bottom of the chamber is reinserted into the top of the chamber by way of recycle line 516 to create a continuous flow of material.

In one embodiment, the chamber 502 is a single physical chamber. In one embodiment, the physical chamber includes 24 beds. In one embodiment, the physical chamber includes less than 24 beds. In one embodiment, the chamber 502 includes two or more physical chambers. In one embodiment, each physical chamber includes 12 beds. In one embodiment, each physical chamber includes less than 12 beds. In one embodiment, each physical chamber includes more than 12 beds. In one embodiment, the physical chambers have an unequal number of beds. In different embodiments, the chamber 502 includes more than two physical chambers.

In one embodiment, a rotary valve 504 controls the flow of material into and out of the bed lines 506 and the net flow of material into and out of the assembly 500 through the assembly inputs and outputs, including primary feed input 508, secondary feed input 536, raffinate output 510, desorbent input 512, and extract output 514. In different embodiments, one or more rotary valves, one or more computing device operated valves, or a combination thereof controls the flow of material into and out of the bed lines 506 and the net flow of material into and out of the assembly 500. A primary feed stream is fed into primary feed input 508. A secondary feed stream, having a lower concentration of para-xylene than the primary feed stream, is fed into secondary feed input 536. A desorbent stream, is fed into the desorbent input 512. An extract stream is withdrawn from extract output 514. A raffinate stream is withdrawn from raffinate output 510.

In one embodiment, the feed stream comprises mixed xylene isomers. In different embodiments, the feed stream comprises mixed xylene isomers as well as heavy impurities, light impurities, or a combination thereof. In one embodiment, the extract stream comprises high purity para-xylene. In one embodiment, the raffinate stream comprises ortho- and para-xylene. In one embodiment, the desorbent stream comprises para-diethylbenzene. In certain embodiments, the desorbent stream comprises a desorbent selected from the group consisting of para-diethylbenzene, para-diisopropylbenzene, tetralin, and the like, and combinations thereof. In one embodiment, the desorbent stream comprises toluene. In one embodiment, the desorbent stream comprises a desorbent other than toluene.

In one embodiment, a line connects each bed line on chamber 502 with a different port on the rotary valve. In one embodiment, 10 of such lines have material actively flowing

during operation while the material in the other 14 lines are stagnant. In one embodiment, greater than 10 of such lines have material actively flowing during operation while the material in the remaining lines are stagnant. The active lines are used to direct a stream of material from each of the assembly inputs and outputs to specific bed lines (4 lines), flush certain input and output lines in a non-dynamic fashion (4 lines), and flush other input and output lines in a dynamic fashion (2 lines).

In one embodiment, the rotary valve has 24 steps, each corresponding to a particular configuration of input and output stream to the bed lines 506. In one embodiment, the number of steps defined by the rotary valve equals the number of beds in chamber 502.

In one embodiment, as the rotary valve moves from one step to the next, the streams from the assembly inputs and outputs move to the next bed line lower on the chamber. For example, at step n, the raffinate stream may initially be pulled from bed line 22. In subsequent steps n+1, n+2, and n+3, the raffinate stream will be pulled from bed line 23, 24, and 1, respectively. The rotary valve also controls a number of flush lines (not shown) to flush the bed lines of material (i.e., extract, feed, raffinate, or desorbent) from a previous step to prepare the bed lines for a future step (i.e., desorbent, extract, feed, and raffinate, respectively).

The rotary valve includes a track for each active stream. Each given track is in constant fluid communication with either an assembly input or output (i.e., 508, 536, 510, 512, or 514) or with an internal flush line. Each given track is also in constant fluid communication with a crossover line. The cross over lines are configured to fluidly connect to a different port at each step of the rotary valve and, as such, connect an assembly input or output or flush line, as the case may be, with a particular bed line.

The routing of the assembly input and output streams by the rotary valve to the chamber 502 for step=n is shown in FIG. 5. In the interest of clarity, the streams 508, 510, 512, and 514 are equally distributed along the height of bed 502. The feed stream 522 is routed to bed line 16, the raffinate stream 524 is routed from bed line 22, the desorbent stream 518 is routed to bed line 3, and the extract stream 520 is routed from bed line 9.

The adsorption zone 532 (Zone I) is defined as the portion of the chamber between the feed stream 522 and the raffinate stream 524, where the para-xylene in the feed stream is adsorbed into the solid adsorbent.

The desorption zone 528 (Zone III) is defined as the portion of the chamber between the desorbent stream 518 and the extract stream 520. The desorbent is selected to have approximately the same affinity for solid adsorbent as the desired xylene isomer. As such, the desorbent washes (i.e., desorbs) the adsorbed para-xylene from the solid adsorbent in the desorption zone 528.

The purification zone 530 (Zone II) is defined as the portion of the chamber between the extract stream 520 and the feed stream 522. In the purification zone 530, the higher affinity para-xylene displaces other xylene isomers within the adsorbent back into the bulk solution, thereby flushing the other xylene isomers down the chamber.

The buffer zone 526 and 534 (Zone IV) is defined as the portion of the chamber between the raffinate stream 524 and the desorbent stream 518. The buffer zone 526 allows the undesired xylene isomers (i.e., ortho- and meta-xylene) to be extracted by the raffinate stream before the extraction of the desired xylene isomer (i.e., para-xylene) is initiated by the desorbent stream 518.

In one embodiment, the secondary feed stream **538**, having a lower concentration of para-xylene than the primary feed stream **522**, is introduced into the chamber within the adsorption zone **532**. The concentration of para-xylene in the bulk liquid within the adsorption zone **532** (i.e., the liquid flowing downward within the chamber) decreases as the para-xylene is adsorbed into the solid adsorbent. The concentration in the bulk liquid in adsorption zone **532** has a maximum concentration of para-xylene at feed point **522** and a minimum concentration at raffinate point **524**. In one embodiment, the secondary feed stream **538** is fed into a bed line on chamber **502** within the adsorption zone where the concentration of para-xylene within the chamber at the point of such bed line is nearest the composition of para-xylene in the secondary feed stream.

At the step=n state depicted in FIG. **5**, bed lines **17** and **18**, as well as the volume of the line connecting bed lines **17** and **18** with the rotary valve and the corresponding volume internal to the rotary valve, contain secondary feed liquid from the previous step=n−2 and step=n−1, respectively. In one embodiment, at the beginning of the step=n state depicted in FIG. **5**, a portion of primary feed stream **522** is directed into primary flush line **540**. As a result, the secondary feed liquid in the primary flush line **540** is driven into the chamber and the primary flush line is backfilled with primary feed liquid.

In one embodiment, the primary flush stream **540** is fed into a bed line on chamber **502** where the concentration of para-xylene within the chamber at the point of such bed line is nearest the composition of para-xylene in the secondary feed stream. At the previous step (i.e., step=n−1), the secondary feed stream **538** was fed into bed line **18**. As such, the concentration of para-xylene in the chamber at bed line **18** at the beginning of step=n is very close to that of the secondary feed stream **538**. As the step=n progresses, the concentration profile within the adsorption zone **532** shifts downward and the concentration of para-xylene at bed line **18** increases as the bulk liquid, richer in para-xylene from primary feed stream **522**, flows downward.

By forcing any secondary feed liquid within the primary flush line **540** (as well as any liquid in the rotary valve and lines connected to the primary flush line **540** filled with secondary feed liquid) rapidly at the beginning of step=n, the concentration profiles between the secondary feed liquid and that within the chamber are best matched. Matching the concentration of (i) material introduced into the chamber **502** with (ii) the concentration at the introduction point prevents concentration spikes in the chamber. Such spikes interfere with the operation of the chamber, reducing efficiency and disrupting the constant composition of extract stream **514**.

In one embodiment, the volume of the primary feed stream **522** directed into the primary flush stream **540** matches the combined volume of the bed line **18**, the associated distributor piping within the chamber, the line connecting the bed line with the rotary valve, and the volume within the rotary valve for the primary flush stream **540**. In one embodiment, because such volume may differ for each step as a result of the pipes and lines connecting the various locations on the chamber with the rotary valve and the tracks within the rotary valve, the volume of the primary feed stream **522** directed into the primary flush **540** is sufficient to fully flush the bed line and associated distributor piping, the line connecting the bed line with the rotary valve, and the volume within the rotary valve for the step position (step=n to step=n+23) having the greatest volume. In one embodiment, the volume of the primary feed stream **522** directed into the primary flush **540** is sufficient to flush the line connecting the bed line with the rotary valve, and the volume within the rotary valve for the step position

(step=n to step=n+23) having the smallest volume. In one embodiment, the volume of the primary feed stream **522** directed into the primary flush stream **540** is sufficient to flush a portion of the secondary feed liquid from the bed line **18**. In one embodiment, the volume of the primary feed stream **522** directed into the primary flush stream **540** is sufficient to substantially flush (i) the rotary valve track and (ii) the line connecting the rotary valve leading to bed line **18**.

At the step=n state depicted in FIG. **5**, bed lines **10-15**, as well as the volume of the line connecting bed lines **10-15** with the rotary valve and the corresponding volume internal to the rotary valve, contain primary feed liquid from the previous step=n−6 to step n−1, respectively. At the end of the step=n state, a secondary flush stream **542** is withdrawn from the purification zone **530** and combined with the primary feed stream **522** by way of stream **624**. In one embodiment, the secondary flush stream **542** is combined with the primary feed stream **522** within the rotary valve. In one embodiment, the secondary flush stream **542** is combined with the primary feed stream **522** before the primary feed stream **522** enters the rotary valve.

In one embodiment, the secondary flush stream **542** is withdrawn from a bed line on chamber **502** within the purification zone **530** where the concentration of para-xylene within the chamber at the point of such bed line is nearest the composition of para-xylene in the extract stream **520**. As a result, the primary feed liquid initially in bed line **10** is flushed into in the chamber **502** at the primary feed point **522** and the primary feed stream is backfilled with liquid similar in para-xylene concentration to that of extract stream **520**. At step=n+1 through step n+6, bed lines **10** through **15**, respectively, are used to remove extract streams, and will have already been preloaded with liquid similar in composition to the extract stream.

In one embodiment, the volume of the secondary flush stream **542** directed into the primary feed stream **522** matches the combined volume of the bed line **16**, the volume of piping in the rotary valve, and the volume of distributor piping to chamber **502**. In one embodiment, because such volume may differ for each step as a result of difference in the bed line piping and tracks within the rotary valve, the volume of the secondary flush stream **542** directed into the primary feed **522** is sufficient to fully flush the bed line such related piping for the step position (step=n to step=n+23) having the greatest volume. In one embodiment, the volume of the secondary flush stream **542** directed into the primary feed **522** is sufficient to fully flush the bed line such related piping for the step position (step=n to step=n+23) having the smallest volume. In one embodiment, the volume of the secondary flush stream **542** directed into the primary feed stream **522** is sufficient to flush a portion of the primary feed liquid from the bed line **16** and preload a portion of the bed line or related piping with material similar in composition to the extract stream **520**. In one embodiment, the volume of the secondary flush stream **542** directed into the primary feed stream **522** is sufficient to substantially flush (i) the piping in the rotary valve and (ii) the distributor piping connecting the rotary valve to bed line **16**.

In one embodiment, the adsorptive separation assembly is used in the process of FIG. **2** as adsorptive separation unit **216**. In such embodiment, primary feed input **508** corresponds to the first feed input **278** and stream **214** in FIG. **2**. The secondary feed input **536** corresponds to the second feed input **280** and stream **206** in FIG. **2**. The raffinate output **510** corresponds to stream **218** in FIG. **2**. The desorbent input **512** corresponds to stream **230** in FIG. **2**. And, the extract output **514** corresponds to stream **220** in FIG. **2**.

Referring to FIG. **6**, a simplified diagram **600** of one embodiment of Applicant's multi-feed column is depicted. The rotary valve, non-active lines, and an active line have been omitted for purposes of clarity. The configuration in FIG. **6** is at step=n.

At step=n, the primary feed stream **522** is introduced into bed line **16**, the raffinate stream **524** is withdrawn from bed line **22**, and the extract stream **520** is withdrawn from bed line **9**.

At the beginning of step=n, a portion of the primary feed stream **522** is fed into a primary flush stream **626** to flush the existing material (i.e., the secondary feed liquid from the last use of the bed line) into stream **540**, through the volume of bed line **18**, the volume of piping in the rotary valve, and the volume of distributor piping internal to chamber **502**. In one embodiment, the primary flush happens rapidly at the beginning of the step=n.

After the primary flush is complete, the bed line **18**, the volume of piping in the rotary valve, and the volume of distributor piping to the chamber **502** are preloaded with material similar in composition to the primary feed stream. At step=n+2, when bed line **18** is used for the primary feed stream, the bed line **18**, the volume of piping in the rotary valve, and the volume of distributor piping to the chamber **502** will have a para-xylene concentration matching that within the chamber at bed line **18**.

Toward the end of step=n, a secondary flush stream **542** is rapidly withdrawn from bed line **10** in the purification zone **530**. The flush completes before the rotary valve transitions to the next step (i.e., step=n+1). Bed line **10** is adjacent to extract bed **9** and, as such, the material in the chamber **502** at bed line **9** and bed line **10** are similar in para-xylene concentration.

At the beginning of step=n+1, in one embodiment, the primary feed material, initially in bed line **16**, has been flushed into the chamber **502** and the bed line and related piping have been preloaded with material similar in composition to the extract material stream. In addition, bed line **10** has also been flushed of primary feed material and preloaded with material similar in composition to the extract material stream. At step=n+1, the extract stream flows through bed line **10**. At step=n+6, the extract stream flows through bed line **16**.

FIG. **7** graphically illustrates a flow profile as a function of time for a prior art flush. The step-time interval **704** on the x-axis represents the time for a full step interval. The step starts at **706** and ends at **708**. The y-axis represents the flow rate and the curve **712** represents the flow rate of the flush at each point in time from the start **706** to the end **708**. The area **710**, represents the total flush volume for the step interval. The flow rate depicted in graph **700** is constant and uniform for the entirety of the step interval.

FIG. **8**(*a*) graphically illustrates an exemplary flow profile as a function of time for a primary flush used in Applicant's system. The step-time interval **808** on the x-axis **804** represents the time for a full step interval. The step starts at **806** and ends at **808**. The y-axis **802** represents the flow rate and the curve **812** represents the flow rate of a primary flush at each point in time from the start **806** to the end **808**. The area **810**, represents the total flush volume for the step interval. The flow rate shown in graph **800** is front-loaded such that substantially all the flush volume occurs toward the beginning of the step interval and drops off rapidly, in one embodiment, at about the step mid-point **814**.

FIG. **8**(*b*) graphically illustrates an exemplary flow profile as a function of time for a secondary flush used in Applicant's system. The step-time interval **808** on the x-axis **804** represents the time for a full step interval. The step starts at **806** and ends at **808**. The y-axis **802** represents the flow rate and the

curve **862** represents the flow rate of the flush at each point in time from the start **806** to the end **808**. The area **860**, represents the total flush volume for the step interval. The flow rate depicted in graph **850** is back-loaded such that substantially all the flush volume begins, in one embodiment, at about the midpoint **805** and ends at time **808**.

In one embodiment, the primary flush drops to about zero flow at or before midpoint **805**. In one embodiment, the secondary flush initiates at or after midpoint **805**. In certain embodiments, there is no flow overlap between curve **812** and curve **862**, i.e., the primary flush and secondary flush each have zero flow rate at midpoint **805**. In other embodiments, the primary flush and secondary flush each have a flow rate greater than zero at midpoint **805**.

Referring to FIG. **9**, a simplified exploded diagram of one embodiment of a rotary valve **900** for use in Applicant's multi-feed adsorptive separation unit is depicted. A base plate **902** includes a plurality of ports **904**. The number of ports **904** is equal the total number of bed lines on the SMB chamber(s). The base plate **902** also includes a plurality of tracks **906**. The number of tracks **906** is equal the number of net input, output, and flush lines for the adsorptive separation unit.

The net inputs, outputs, and flush lines are each in fluid communication with a different track of the plurality of tracks **906**. Crossover lines **910** place a given track **906** in fluid communication with a given port **904**. As the rotor plate **908** rotates as indicated by arrow **914**, each track **906** is placed in fluid communication with the next successive port **904** by crossover line **910**. As such, the rotary valve **900** ports each of the net inputs, outputs, and flush lines to a different port **904**. With each full rotation of the rotor plate **908**, a given input, output, or flush line will have been routed to each of the ports **904**.

In one embodiment, the net inputs include a primary feed input, a secondary feed input, and a desorbent input, the net outputs include an extract output and a raffinate output, and the flush lines include two constant flow flush lines and three dynamic flow flush lines. In this embodiment, the rotary valve comprises 10 tracks, as depicted in FIG. **9**.

In another embodiment, the net inputs include a primary feed input, a secondary feed input, and a desorbent input, the net outputs include an extract output and a raffinate output, and the flush lines include two constant flow flush lines and two dynamic flow flush lines. In this embodiment, the rotary valve comprises 9 tracks. As would be apparent to those skilled in the art, rotary valves of less than 9 tracks and greater than 10 tracks could be constructed in similar fashion by adding or removing tracks and associated crossover lines accordingly.

Referring to FIG. **10**, a diagram of an embodiment of Applicant's adsorption separation assembly **1000** having a multi-feed column and a ten (10) track rotary valve is depicted. The assembly **1000** comprises an adsorption chamber **502** and a rotary valve **1002**. The rotary valve **1002** is represented as a block with ten individual tracks **1003** connecting the stationary lines **1004** with certain bed lines **1006**. The rotary valve is shown in the step=n configuration. As the rotary valve advances to the step=n+1, the tracks shift downward such that the stationary lines **1004** are connected with the next bed line **1006** down the adsorption chamber **502**. For example, a track connecting an input with bed line **23** at step=n, will connect the input to bed line **24** at step=n+1 and bed line **1** at step=n+2.

Three input streams, a desorbent stream **1008**, a primary feed stream **1010**, and a secondary feed stream **1012**, feed material into the rotary valve. Two output streams, an extract stream **1014** and a raffinate stream **1016**, receive material

from the rotary valve. A number of flush lines, **1018**, **1020**, **1022**, and **1024**, recirculate material in preparation for upcoming steps.

The extract flush line **1018** (i) flushes extract material from the distribution line **1026** that was last used as an extract output and (ii) loads the distribution line **1026** with material similar in composition to the desorbent stream **1008**. As used herein, the usage "bed line **1026**" refers to the physical bed line on the outside of chamber **502**. Whereas, the usage "distribution lines **1026**" refers to the volume within the physical bed line **1026** external to chamber **502**, the distributor piping within chamber **502** connected to bed line **1026**, and the channels through rotary valve **1002** connected to bed line **1026**.

The material in the distribution line **1026** is loaded with high purity para-xylene material. As such, reintroduction of high purity para-xylene into chamber **502** when the bed line is later used as a desorbent input, which would disrupt the separation process within the chamber, is avoided.

During the extract flush, material is withdrawn by way of extract flush bed line **1028**, a bed line below the desorbent bed line **1026** on chamber **502**. In one embodiment, bed line **1028** is directly adjacent to the desorbent bed line **1026**. In one embodiment, the bed line **1028** is separated from desorbent bed line **1026** by at least one bed line. As such, the material loaded into the distribution line is similar in composition to the desorbent stream **1008**.

The distribution line was last used as an extract output. As such, the material flushed out of the distribution line comprises extract material from a previous rotary step. In one embodiment, the flushed material is combined with extract stream **1014**.

In one embodiment, the amount of material pulled from the chamber **502** into the distribution line **1028** is substantially the same as the volume of the distribution line **1028** and extract flush line **1018**. In one embodiment, the amount of material pulled from the chamber **502** into the bed line and associated distributor piping is less than the volume of the distribution line **1028** and extract flush line **1018**.

A primary flush line **1020** flushes feed material from the upper portion of purification zone **530** to the lower portion of purification zone **530**. Distribution line **1032**, which serves as the primary flush out, was most recently used in a previous step as the primary flush in. Before the primary flush, in one embodiment, the material within distribution line **1032** comprises material similar in composition to the exact stream **1014**.

Distribution line **1034**, which serves as the primary flush in, was most recently used in a previous step as the primary feed input. Before the primary flush, the material within distribution line **1034** comprises primary feed material.

The primary flush line **1020** loads material from a location on the chamber **502** proximate the extract bed line **1030** into primary flush out distribution line **1032**. In one embodiment, the primary flush out bed line **1032** is directly adjacent to the extract bed line **1030**. In one embodiment, the primary flush out bed line **1032** is separated by the extract bed line **1030** by at least one bed line.

Material previously in distribution line **1034** is flushed into the chamber **502** at a location proximate the primary feed input bed line **1036**. In one embodiment, the primary flush in bed line **1034** is directly adjacent to the primary feed input bed line **1036**. In one embodiment, the primary flush in bed line **1034** is separated by the primary feed input bed line **1036** by at least one bed line.

In one embodiment, the primary flush is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*b*). In one

embodiment, the primary flush is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*a*). In one embodiment, the primary flush has a uniform flow profile throughout the rotary valve step. In one embodiment, the amount of material pulled from the chamber **502** into the distribution line **1032** is substantially the same as the volume of distribution line **1032**. In one embodiment, the amount of material pulled from the chamber **502** into the distribution line **1032** is greater than the volume of distribution line **1032**. In one embodiment, the amount of material pulled from the chamber **502** into the distribution line **1032** is substantially the same as the volume of distribution line **1032** and primary flush line **1020**. In one embodiment, the amount of material pulled from the chamber **502** into the distribution line **1032** is greater than the volume of distribution line **1032** and primary flush line **1020**. As such, the primary flush out distribution line **1032** is loaded with material similar to the extract stream **1014**, thereby avoiding the introduction of a quantity of feed material into the extract stream **1014**.

The feed flush line **1022** (i) flushes remaining secondary feed material from a previous step into the chamber **502** and (ii) loads the distribution line with primary feed material for an upcoming step. A portion of the primary feed stream **1010** is diverted into the feed flush distribution line **1038** by way of feed flush line **1022**. The distribution line **1038** was more recently used in a previous step as a secondary feed line. As such, the material within distribution line **1038**, before the feed flush, comprises secondary feed material. The distribution line **1038** will be used next as the primary feed input. The feed flush line **1022** loads the distribution line **1038** with primary feed material and drives any remaining secondary feed material into the chamber **502**.

In one embodiment, the feed flush bed line **1038** is directly adjacent to the secondary feed bed line **1040**. In one embodiment, the feed flush bed line **1038** is separated from the secondary feed bed line **1040** by at least one bed line.

In one embodiment, the feed flush is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*a*). In one embodiment, the feed flush is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*b*). In one embodiment, the feed flush has a uniform flow profile throughout the rotary valve step.

A raffinate flush line **1024** flushes raffinate material in the raffinate flush distribution line **1042**, from the most recent step, into the raffinate stream **1016**. The raffinate flush loads the raffinate flush distribution line **1042** with material higher in para-xylene content than is present in the raffinate stream **1016**. As such, during the next use of the bed line **1042**, for secondary feed input, the material in the distribution line **1042** will be more similar in composition to the secondary feed input.

Referring to FIG. **11**, a diagram of an embodiment of Applicant's adsorption separation assembly **1100** having a multi-feed column and a nine (9) track rotary valve is depicted. The assembly **1100** comprises an adsorption chamber **502** and a rotary valve **1102**. The rotary valve **1102** comprises nine individual tracks **1103**.

Extract flush **1018** and raffinate flush **1024** operate in the same manner as described in FIG. **11**. Primary flush **1104** operates in the same manner as stream **624** as described in FIG. **6**. Feed flush **1106** flushes secondary feed material, originally in distribution line **1108** from the most recent step, into the secondary feed stream **1012**. Feed flush **1106** also loads distribution line **1108** with material having a higher concentration of para-xylene than is present in the secondary feed stream **1012**, in preparation for a future step where bed line **1108** is used as a primary feed input.

In one embodiment, the primary flush **1104** is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*a*). In one embodiment, the primary flush **1104** is non-uniform, having a flow profile similar to that depicted in FIG. **8**(*b*). In one embodiment, the primary flush **1104** has a uniform flow profile throughout the rotary valve step. In one embodiment, the embodiment depicted in FIG. **11** is used to implement the flow diagram depicted in FIG. **6**.

Each of the disclosed processes avoids the vaporization of the isomerization product stream to extract C9 aromatic impurities. As such, the disclosed processes consume substantially less energy, resulting in lower operational expenditures, and require an overall reduction in equipment costs, resulting in substantially lower capital expenditures, as compared to prior art xylene production processes.

Referring to the foregoing paragraphs, this invention is described in preferred embodiments in the following description with reference to the Figures, in which like numerals represent the same or similar elements. Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

The described features, structures, or characteristics of the invention may be combined in any suitable manner in one or more embodiments. In the above description, numerous specific details are recited to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

While the invention is described through the above-described exemplary embodiments, it will be understood by those of ordinary skill in the art that modifications to, and variations of, the illustrated embodiments may be made without departing from the inventive concepts disclosed herein. For example, although some aspects of separating para-xylene has been described, those skilled in the art should readily appreciate that functions, operations, decisions, etc., of all or a portion of each step, or a combination of steps, of the series of steps described may be combined, separated into separate operations or performed in other orders. Moreover, while the embodiments are described in connection with various illustrative processes, one skilled in the art will recognize that the methods and processes described herein can be embodied using a variety of techniques. Furthermore, disclosed aspects, or portions of these aspects, may be combined in ways not listed above. Accordingly, the invention should not be viewed as being limited to the disclosed embodiment(s). The scope of the invention should be determined with reference to the pending claims along with their full scope or equivalents, and all changes which come within the meaning and range of equivalency of the claims are to be embraced within their full scope.

What is claimed is:

1. An apparatus for separating para-xylene from a plurality of aromatic compounds, comprising:
a first adsorptive separation unit comprising a rotary valve comprising more than 8 tracks, said first adsorptive unit being in fluid communication with said rotary valve and comprising a first feed input and a second feed input;
a second adsorptive separation unit; and
a raffinate column in fluid communication with both said first adsorptive separation unit and said second adsorptive separation unit.

2. The apparatus of claim **1**, further comprising:
an isomerization unit in fluid communication with both said raffinate column and said second adsorptive separation unit.

3. The apparatus of claim **1**, wherein:
said raffinate column comprises a first input, a second input, and an output;
said first adsorptive separation unit is in fluid communication with said first input; and
said second adsorptive separation unit is in fluid communication with said second input.

4. The apparatus of claim **3**, further comprising an isomerization unit in fluid communication with said output.

5. The apparatus of claim **4**, further comprising:
a first extract column in fluid communication with the first adsorptive separation unit; and
a second extract column in fluid communication with the second adsorptive separation unit.

6. The apparatus of claim **5**, further comprising a xylene fractionation unit in fluid communication with said second extract column.

7. The apparatus of claim **6**, wherein said first extract column is configured to produce a para-xylene product stream.

8. The apparatus of claim **5**, further comprising a xylene fractionation unit in fluid communication with said first adsorptive separation unit.

9. The apparatus of claim **8**, further comprising a finishing column in fluid communication with the first extract column.

10. The apparatus of claim **1**, further comprising a drag line in fluid communication with said raffinate column.

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